THE USE OF ACCELERATED PAVEMENT TESTING AS AN ACCELERATED LEARNING FACILITY

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ABSTRACT

The benefits of an accelerated pavement testing program are often discussed in terms of improvements to pavement design and analysis, the introduction of new materials and construction techniques, and a better understanding of long term pavement performance. A highly significant, and often overlooked, additional benefit is the opportunity an accelerated pavement testing program creates for staff training and learning. Pavement engineering represents only a small proportion of the curriculum at most tertiary engineering education institutions, and it is widely recognised that there is a current global shortage of skilled pavement engineers. The paper describes how the Australian operation of the Accelerated Loading Facility (ALF) has exposed student and graduate engineers to a wide range of learning experiences. Some case studies are presented to demonstrate the range of learning opportunities presented by accelerated pavement testing.

1. INTRODUCTION

The benefits of an accelerated pavement testing program are often discussed in terms of improvements to pavement design and analysis, the introduction of new materials and construction techniques, and a better understanding of long term pavement performance.

Generally. proposals for new accelerated pavement testing (APT) facilities focus on the need to verify existing pavement design and construction practices [1], a desire to quantify the effects of increased traffic levels and loads on an established infrastructure, and the use of alternative materials and treatments within pavement structures [1], [2].

Economic analyses have demonstrated that benefit-cost ratios of completed APT research projects have typically exceeded 4 [3] and have risen as high as 13 [3], [4]. These analyses have focussed on the road agency cost savings, both asset establishment and asset preservation costs, that have been realised as a result of the pavement design, construction and maintenance technologies and practices demonstrated by APT research work.

The potential technological benefits of an APT program can, therefore, be considered to have been clearly demonstrated.

Additional to these demonstrated immediate economic benefits, however, it is suggested that an APT facility and associated research program can create an excellent environment for staff training and increased learning. Rust et al. [5] briefly described the educational benefit of the long-running Heavy Vehicle Simulator (HVS) program in South Africa.

This paper presents the educational benefits that three young engineers (two graduates, and one student) have realised via their association with the Accelerated Loading Facility (ALF) operated by ARRB Group (formerly the Australian Road Research Board) in Australia. The case studies demonstrate benefits that were obtained in an ad hoc manner, and it is suggested that significantly increased benefits could be achieved within a more structured learning program.

2. ACCELERATED LOADING FACILITY

The ALF is a full-scale pavement test system designed and manufactured by the Roads and Traffic Authority, NSW. It is the only APT equipment operating in Australia. The ALF is owned and operated by ARRB Group and is used to assess:

- the estimated life of existing pavements
- the validity of new methods of pavement design
- the suitability of marginal, improved or innovative pavement materials
- the effectiveness of changes in pavement construction procedures
- the applicability of pavement rehabilitation techniques
- the effects of climate and traffic on performance.

Driven rolling wheel loading is applied in one direction to pavement test sections 12 m in length at a constant speed of about 20 km/h. The half-axle test wheel loads can be varied in 10 kN increments from 40 kN to 80 kN. The loading can be channelised or applied over any transverse distribution of load up to 1.2 m width. A normal transverse distribution of up to 1.2 m or 0.9 m wide is commonly used to simulate traffic wander across the road.

The cycle time for each load is about 9 seconds, which corresponds to approximately 370 load cycles per hour or, depending on the percentage of operating time, about 50,000 cycles per week.

Whilst ALF is a mobile, relocatable machine, in recent years it has mainly been located at a permanent site in Melbourne, inside a large shed (54 m long and 20 m wide). This has allowed much greater control of the moisture condition of the test pavements (see Figure 1).

Figure 1. Accelerated Loading Facility operating inside shed

The focus of recent ALF research work has been the field validation of material characterisations and design methods, rather than proof loading of pavement structures. As a result, ALF research projects have a high component of associated laboratory work, often involving the development of new, or the refinement of existing, test procedures.

3. PAVEMENT EDUCATION IN AUSTRALIA

Generally, engineering courses at Australian tertiary institutions have had little focus on pavement engineering. The typical exposure undergraduate civil engineering students have to pavement engineering is limited to an overview of the terminology used and the rudiments of thickness design, usually with little focus on pavement material characterisation, distress types and mechanisms, or long term maintenance and performance issues.

Farrelly and Mavin [6] noted that, traditionally, Australian road authorities took the lead in the training of personnel, but that since the late 1980s economic constraints, the imposition of staff ceilings and the emergence of corporatisation within agencies had resulted in the authorities severely contracting their education and training role. Farrelly and Mavin described the establishment of a pavement studies and research centre, a partnership between road authorities and industry, in the mid-1990s to, at least partly, address the emerging gap in pavement engineering training. The centre, now titled the Centre for Pavement Engineering Education (CPEE), has largely focussed on distance-based, post graduate course work.

Australian universities currently undertake little pavement-related research, and have had extremely limited involvement with the national pavement research agenda or the APT program. To date only two completed, and two ongoing, PhD theses have been partly based on ALF research work. These studies have all been conducted by members of ARRB staff, and all on a part-time basis.

Some case studies describing how research work conducted using the ALF has been used as a training aid for graduate engineers are now presented

4. CASE STUDIES

4.1 Case Study No. 1 – Multi-Depth Deflection Gauges

In September 2005, a graduate engineer joined ARRB in a rotational graduate position that involved changing work area every six to nine months. He had recently completed a Bachelor of Engineering (Civil) degree at the University of Melbourne. His initial involvement in the ALF program came about when he was temporarily to assist with a repair after a mechanical breakdown. His association with the ALF program has continued since that time, despite his roles in other work areas.

Whilst his subsequent ALF work has been varied, it has mostly been focussed on the installation of multi-depth deflectometers (MDD) in test pavements (see Figure 2). The MDD system used during recent ALF experiments are of South African design. Whilst they are capable of providing excellent data, their installation is intricate and considerable problems arose during initial trials.

The installation of the MDD system involved drilling small-diameter boreholes to a depth exceeding 3 metres, through bound and unbound pavement layers. Through practice and experience the team improved their drilling skills, developed an understanding of which drill bits to use for different pavement materials, and the means of minimising drill jams. Less obviously, the graduate gained an understanding of pavement composition, the performance of bound and unbound materials, the effect of confining pressures on material strength and the sensitivity of granular materials to changes in moisture content.

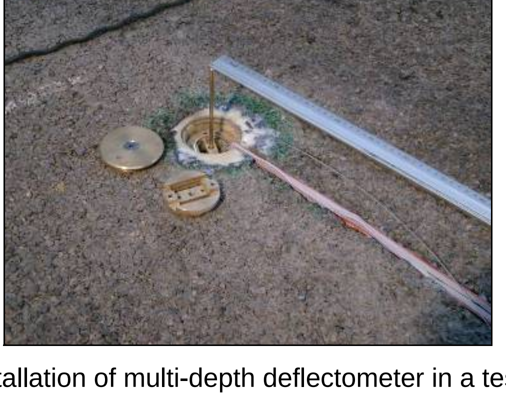

Figure 2. Installation of multi-depth deflectometer in a test pavement

The MDD system allows the absolute deflection of a pavement to be measured by modules installed at several depths within the pavement. The installation of modules required the graduate to develop a good understanding of how the modules worked and how they were integrated into the complete system. This required the development of new visualisation skills, especially since the modules are installed 'blindly' underground. Without being consciously aware of it, the graduate considerably increased his understanding of road pavements from the limited information provided during his University course of only the year before.

The deflection measuring modules in the MDD system are linear variable differential transducers (LVDT), and data is logged onto personal computers via data acquisition and signal conditioning hardware. The main lessons learnt from this aspect of the installation related to the interpretation of data from noisy data signals, the tracking of electrical noise and, most significantly, an understanding of data validation and a wary caution in accepting data from complex systems. The ability to say that data 'looks right' was only made possible because of the understanding of pavement behaviour already gained.

As a result of the experience gained installing MDD systems for the ALF program, the graduate became a key member of the team involved in the examination of the relative damaging effects of quad axles and triaxles [7]. The graduate's photographic skills were also used to document processes and the condition of test pavements and equipment. This required an adjustment to be made in terms of meeting the requirements of technical photography rather than artistic photography.

"Involvement in the ALF program has given me a much better understanding of pavements and how they react to loading in the short and the long term. These pavement properties, and the knowledge of them, underpin everything that happens at ALF to the point that you don't actually think about it and it becomes second nature. In my ALF work I have been given a lot of responsibility, which is not taken lightly, and the results that have come from some of my work form a large part of a million dollar research program. We were doing things that were not common, and in some cases had never been done before. As such, often there wasn't a clear guidebook to read, or local experts to advise. This put the responsibility directly onto me to ensure everything worked, and to think fast if it didn't. Many of the skills I have learnt through the ALF program may not be appear to be directly applicable elsewhere; however, taking a step back, the process of going through learning those skills was exceedingly valuable."

4.2 Case Study No. 2 – Field and Laboratory Testing

A second graduate engineer had recently obtained a combined science/engineering degree. However, his experience of pavement engineering was only a 10 hour component of one subject out of his five years of undergraduate study.

The time the graduate engineer joined ARRB coincided the commencement of a new ALF test project. The graduate was involved throughout the construction processes, from the planning and plant selection discussions, through removal of existing pavements and construction, to the placement of the final surfacing. As the construction was conducted by a small team, and inside the ALF shed, the work site was safer than a 'normal' road project and offered more opportunity to observe construction techniques and converse with the operators. Most of the construction took place in a concentrated month of activity, with experienced personnel readily at hand to answer questions as they arose. It is unlikely that the graduate would have been able to observe a similar range of activities on a typical road construction project [8].

During the construction works, the graduate undertook or observed a wide range of pavement and materials tests. Surveying techniques learnt in undergraduate study were put to use in undertaking, processing and analysing the extensive construction levels surveys. Moisture contents were determined using samples extracted from the pavements, and subsequently tested in the laboratory. The experimental design required that the base materials not be sealed until their moisture content had reach a target of 80-85% of their optimum moisture contents. The four pavements dried back at different rates, and the graduate regularly carried out moisture content assessments and analysed the results to enable the scheduling of the final surface sealing. Whilst moisture content monitoring and laser levelling were reasonably basic tasks, the analysis of results and recommendations for future actions based upon those results were critical to success of the experiments.

During the ALF trafficking of the test sections, the graduate managed the collection of routine pavement condition measurements including transverse surface profile (see Figure 3), surface macro-texture, FWD deflection, Nuclear Density Meter density and moisture content readings, and oven dried moisture contents. In developing experimental plans he learnt to make broad predictions of likely pavement behaviour, and became familiar with the early warning signs of pavement failure. Management of the condition measurement collection process was a key component of the role, including the coordination of personnel, field equipment and laboratory resources.

Figure 3. Transverse profile measurement of test section under ALF

In addition to involvement in the ALF trafficking of pavements, the graduate also played a major role in the on-going laboratory testing program associated with an earlier ALF project. This project involved the flexural fatigue performance of two plant mixed cement-treated crushed rock pavements, and the laboratory testing program largely consisted of the measurement of the flexural strength, modulus and fatigue characteristics of long-term samples. The graduate learned how to undertake the modulus testing at stress levels high enough to ensure a deflection response could be measured, but low enough to ensure that the sample was not damaged during loading. A standard fatigue test involved increasing the loading strain to levels damaging the sample, and measuring the number of loading cycles applied before the sample reached half of its initial flexural modulus and then ultimately broke. Depending on the load level, tests could take hours or days to complete. By varying the initial strain level applied, the graduate was able to develop a relationship between the strain and the number of cycles to failure for each material. By increasing the range of strain levels tested, and therefore the duration of the tests, he was able to progressively improve the quality of the fatigue characterisation model. It was vital that, whilst still developing the fatigue performance mode, the results to date were analysed to enable predictions as to how long a given sample, and a given load level, was expected to last.

In the space of a year, the graduate engineer's experience of pavement engineering grew from the limited instruction he had received as an undergraduate to the observation and interaction during road construction, the collection and analysis of pavement condition data, the observation of a pavement's life from construction to ultimate end of life, the conduct of laboratory testing and the management of laboratory personnel and equipment.

"The ALF program enabled me to see the entire life of a pavement, from construction through to pavement failure. Field and laboratory testing I have been involved with has given me an appreciation of pavement behaviour, and valuable experience in managing personnel and equipment, including laboratory test programs. The wide range of experiences gained in a short period of time would be hard to obtain elsewhere."

Case Study 3 – Engineering Student

The third case study involved a then a civil engineering student who worked at ARRB as a vacation student at the end of the third year of a four year civil engineering degree. His exposure to pavement engineering at university was very limited.

A large component of the student's time was spent assisting with the maintenance of the ALF machine and the day-to-day running of the site. Throughout ALF trafficking of the test pavements, the graduate routinely collected transverse surface profile measurements and response to load measurements using the installed MDD systems. As he was also responsible for checking the quality of the data collected, he had to visualise the interaction between pavement loads and multiple responses within the pavement structure.

The student also assisted during trenching operations, and was able to observe the condition of the trenched pavements with depth. As the test pavements were located inside the ALF shed, the trenching exercises were subject to less time and other constraints than would occur on a normal road subjected to live traffic under a traffic management scheme.

The other major component of the student's work was the preparation of laboratory samples of the same cement-treated crushed rock that had been trafficked by ALF. After undertaking volumetric calculations to ensure that target mix designs were met, samples were compacted in a slab compactor and flexural beam samples saw-cut from each slab. The student was responsible for testing the prepared samples, and measuring the flexural modulus, flexural strength and fatigue performance. During this process he gained experience in time management, laboratory procedures and documentation, and was able to consider some of his undergraduate geotechnical and material behaviour studies in tangible ways.

"I was really impressed with the variety of work that I was able to do as part of the ALF research team. Fellow students doing vacation work were often stuck doing the same dull task over and over throughout their work. I had a much more interesting time."

CONCLUSIONS

The paper has described how the Australian operation of the Accelerated Loading Facility (ALF) has exposed student and graduate engineers to a wide range of learning experiences. Some case studies have been presented to demonstrate the range of learning opportunities presented by accelerated pavement testing. The experiences and knowledge gained in the case studies were very varied. In a short period of time the young engineers were exposed to the following activities, and in many cases given responsibility for their conduct:

- pavement terminology and the roles of materials within pavement structures
- selection of plant for construction
- removal of existing pavements by rotormill/profiler
- bulk mixing of pavement materials in a pugmill
- quarry operation
- pavement construction, including surfacing
- construction-related testing, including levels and Nuclear Density Meter assessments
- laboratory determination of moisture content of materials
- Falling Weight Deflectometer measurement and the analysis of the results
- ALF test pavement condition assessment, including measurement of changes in transverse profile of the road surface and surface macrotexture with increasing application of load cycles
- preparation of testing samples from field extracted material
- preparation of testing samples in the laboratory
- flexural modulus, strength and fatigue testing, analysis and reporting.

Whilst many of these activities are commonly conducted throughout the road industry, it is uncommon for a recent engineering graduate to be exposed to such a range of activities within the first twelve months of their professional career. Beyond this list of activities the case studies also showed how

professional responsibility was developed, including resource and staff management and working within a team.

In addition, the engineers gained experience and skill in more specialist areas such as the measurement of pavement response to load using strain gauges and multi-depth deflectometer gauges, pavement trenching and related investigations, and technical photography. The ALF program also proved to be an excellent environment for developing skills in project management, technical writing and oral communication.

Throughout their time with the ALF program the engineers were working as pat of a research team, learning and contributing to the experimental program through interaction with experienced pavement researchers. The experience of others, and their own observations during accelerated pavement testing, allowed the young engineers to develop a ‘feel’ for pavement behaviour. It is considered unlikely that engineers unfamiliar with APT work would have a similar level of understanding at the same stage in their careers.

The three cases demonstrate that young engineers can benefit hugely from even short-term involvement in an APT program, and that there are many benefits realised from the process of involvement with APT in addition to those that are to be had from the research outputs themselves.

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